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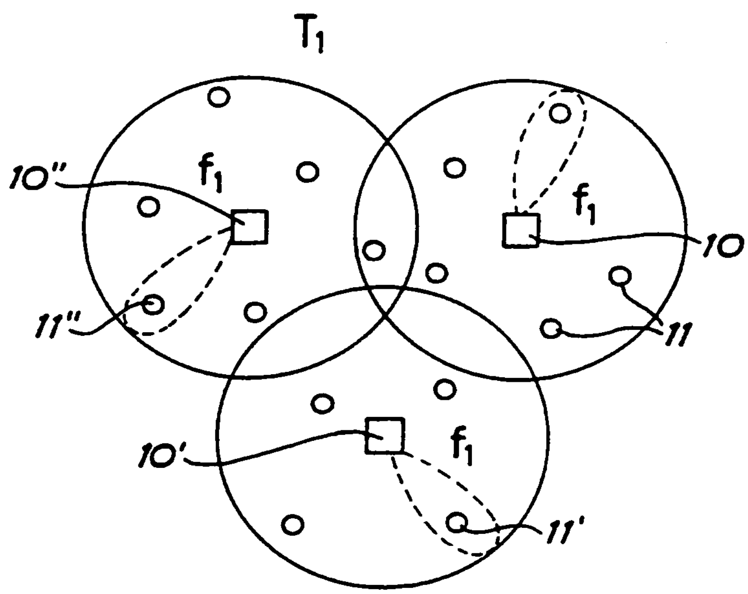
(54) Title: METHOD AND SYSTEM IN A WIDE AREA RADIO COMMUNICATION NETWORK



(57) Abstract

The invention relates to a method and a system in a wide area radio communication network, the network comprising at least two central stations (10), each central station being assigned to at least one peripheral station (11). According to the method radio transmission at specific frequencies between stations positioned along an arbitrary line is coordinated during all time intervals. The stations are provided with timing means (13), and transmitting and receiving means (14; 41, 42) for transmitting and receiving during predetermined time intervals in a predetermined direction.

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METHOD AND SYSTEM IN A WIDE AREA RADIO COMMUNICATION NETWORK

The invention relates to a method and a system in a wide area radio communication network, comprising at central stations, each cental station being assigned to one or more peripheral station.

To make possible for a plurality of users of wide area mobile or stationary radio systems to utilize common communication resources methods of time and/or frequency sharing (e.g. TDMA, ALOHA, CSMA, Polling, FDMA) have been developed. The first method developed was frequency sharing. The Nordic mobile telephone system NMT is based on this method. According to the frequency sharing method the users are allocated a certain channel at a certain frequency during the communication. Time sharing is a more modern method.

Digital wide area systems normally use time sharing, some times in combination with frequency sharing.

A drawback of the prior art methods for sharing resources is that the central station disposed in the center of the area must be able continuously to reach the peripheral stations spread out in each cell area or sector (e.g. within 360° or 90°.; see figs 1 and 2).

The quality of digitally transmitted signals is effected by reflection and diffraction, see fig 3. By using omni directional or sector directional antennas the transmission capacity is limited. This is a difficult problem especially in mobile systems.

Another drawback in current systems is that an ongoing information process between two stations results in transmission and reception in undesired

directions. Small cell configurations such as those shown in fig 4 are common in radio area networks.

EP,A3,0201254 discloses a more developed radio communication system which utilizes spot beams, time division multiple access, and frequency-use to provide communication service from a central station to remote customers within a system service region. The central station provides multistage switching on intermediate frequency level to form a spotted beam in different directions so as to permit the respective sharing of radio transmitters and receivers over a major number of antenna transmitting and receiving ports. At the super central station, each section of the service area is covered by a different one of a raster of spot beams which are switched in accordance with a TDMA frame. A small number of transmission frequencies are re-used by different spot beams. The signal output energy is constant, regardless of the distance between the central station and the customer stations.

An object of the present invention is to overcome limitations and drawbacks of the prior art systems mentioned above. Another object of the present invention is to minimize interference between stations and to minimize the total power consumption of the system. To achieve these objects the method and system according to the invention have obtained the characteristics appearing from claim 1 and claim 5, respectively.

In order to explain the invention embodiments thereof will be described in more detail below with reference to the accompanying drawings, wherein

figs 1-6 are representations of prior art communication systems,

fig 7 shows a timing sequency in the system shown in figs 5 and 6,
fig 8 is a representation of the buffering principle which takes place in the system according to figs 5 and 6,
fig 9 is a view from above of an embodiment of a system according to the invention during a specific time interval,
fig 10 shows the system in fig 9 during another time interval,
fig 11 shows a central station according to the invention,
fig 12 shows another embodiment of the invention utilizing phase array antennas,
fig 13 is a representation of a timing synchronizing system utilized in an embodiment of the invention,
fig 14 is a representation of a phase displacement system utilized in an embodiment of the invention,
fig 15 is a representation of a system according to the invention,
figs 16, 17 and 18 are representations of a system according to the invention transmitting in duplex and semi duplex,
figs 19 and 20 are representations of different time frames for different subsystems in duplex and semiduplex,
fig 21 is a block diagram of a system configuration,
fig 22 is a representation of the configuration in fig 21
fig 23 is a block diagram of a sub-system, and
figs 24 to 26 are representations of diffferent methods of connecting systems according to the invention to external networks.

The information transmission between two stations in a prior art system using spotted beams takes place during a specific time interval or time slot, many slots constituting a frame, and in a specific direction. The transmission is normally repeated continuously. With reference to figs 5 and 6 it is clear that when transmission is taking place between two stations, the stations are directed towards each other with regard to the transmitting as well as the receiving direction.

The time diagram in fig 7 shows how the transmission between stations is divided into frames or time intervals.

When the information flow is continuous the information is transmitted as packets in time slots which are stored and rebuilt at the receiving unit and then retransmitted from the system in the original shape. The transmission is transparent to the user. There is a certain delay in transmission mainly caused by the package transmission. Buffering and the rebuilding, see fig 8, in which 11 and 12 are references for peripheral stations and 10 for a central station. The time delay between each package or the repeated time slot in a frame is adjusted to the time delay acceptable in connected services. In public telephone networks a delay of up to 50 ms may be acceptable.

The wide area telecommunication, system according to the invention is intended for all types and combinations of telecommunication services, such as analog and digital telephone transmission, high quality sound and image transmission, low-speed asynchronous data transmission and synchronous data transmission, all services in corporation with other types of networks and services.

It is also possible to implement the system according to the invention for a specific service or for a specific combination of services. During the transmission phase the antenna of a central station is always directed towards a specific peripheral station, but a peripheral station may under certain circumstances, such as in mobile applications, utilize an omni directional antenna and/or a adaptive directional antenna.

Each station dynamically and continuously redirects itself to the next station in turn for transmission. To keep the system capacity high the redirection delay is made very short in relation to the time of the timeslots. In the system according to the invention the redirection time delays are about or less than 1 microsecond which means that the time losses due to redirection are marginal. At a channel capacity of 2 Mbite/s and 50 active stations less than 1 per cent of transmission time is lost due to the redirection.

The system according to the invention is intended for stationary peripheral stations as well as mobile type peripheral stations. In a system comprising stationary peripheral stations the geographical position of each of the stations is stored. Position data are utilized when the central stations calculate and control the peripheral stations transmitting and receiving direction, time assignment according to traffic demand and timing in other subsystems, power and when applicable carrier frequency in order to optimize capacity and quality and minimize interferance. When a new station is connected or an active station is disconnected the system automatically recalculates transmission control data. Central stations use time slots in the

frames during which the area covered by that central station is scanned to locate and identify any new station added and any previous active station disconnected or reconnected. Basically a central station of the system has three basic states or modes:

A) Identifying stations and compensating for distance variations, for correct timing and power control.

B) Controlling station traffic.

C) Transferring user and system information.

Optionally the system performs also:

D) Scanning for identifying non-active and new stations and the locations thereof.

The system includes a central station antenna which is directed towards one specific peripheral station during short time intervals during which information is transferred, so as to achieve optimized signal strengths and minimized interference for the normal information exchange. The information exchange which is well defined in time as well as in direction makes possible a simultaneous reuse of the frequency in the vicinity of said stations, as long as the transimission direction during that time interval is different. From figs 9 and 10 it is apparent how three different central stations 10, 10', 10'' can transmit to three different peripheral stations 11, 11', 11'' and use the same frequency f_1. This is possible because of the highly directed antenna system, of the central station and because of the power, information transfer and timing control applied to the system. fig 9 shows the transmission taking place during time interval t_1 and fig 10 during time interval t_2. During certain time

periods the central stations search and scan for new stations or movements of stations. The central stations are not directed towards any specific peripheral station during said time periods.

The system utilizes dynamically controlled antennas 41 and the principle of this type of antennas is shown in fig 11. In one implementation of the system phase array antennas 42 are used, see fig 12. The construction of the phase array antennas depends on the application. In fig 12 four plane phase array antenna elements 17, each of which covers 90°, are combined so as to cover a full circle for one radio transmitter/receiver. Alternatively, one plane phase array element is combined with one transmitter/receiver in order to allow the central station to serve a sector. Each of the elements is constructed to have a well defined transmission direction in space.

One central station 10 and the peripheral stations 11 connected thereto comprise one subsystem which combined with more subsystems forms a larger communication system that cover a principally unlimited area as illustrated in figs 21 and 22. Different configuration types are possible, such as those shown in figs 24, 25 and 26 with decentralized or hirarcial structures. Further, all or some of the stations may be provided with dynamically controlled directional antennas.

One implementation of timing control between subsystems is shown in fig 13 where the central stations 10 receive synchronizing signals from an external reference source and communication channel such as a satellite 21, radio/TV transmitter etc. The timing control and traffic coordination between subsystems to avoid interference could also take

place through the public telephone network or through central stations which are set up to be synchronized and exchange control data with adjacent stations, 80, see figs 21 and 22. Compensation for and control of time reference differences, 34, between different adjacent sites may be included in advance by compensating for the relative time difference between different geographically separated stations. Alternatively, the central stations are provided with a frame stability which makes synchronization unnecessary. If synchronization is not applied adaptive fault detection methods are used to coordinate traffic in the subsystems.

Fig 14 shows a simplified arrangement to which there is applied a dynamic time slot allocation in dependence of the traffic for each central station indenpendent of traffic analyse on other central stations. To minimize the interference between central stations the scanning beam or beams at each central station can be phase delayed and/or combined with a quality detection to perform communication as mentioned above. Thus, in this way risk of interference is minimized without a dynamic traffic coordination between none-adjacent central stations.

A way of avoiding interference between different substations is simply not to allow information exchange in some directions during some time intervals. Areas 22 in fig 15a are referenced as prohibited zones and no transmission is allowed in those areas. The unit giving the reference number 23 is a source of interference, which can be constant in time.

At certain time intervals a pair of station in each subsystems are bound to interfere when they

transfer information at the same frequency. See figure 15b. Two such stations are referenced as a pair at risk. 24, 25, 26, 27, 28. However, for fixed applications pairs at risk are known in advance and the time intervals given to the stations in a pair at risk are chosen by the control system so as to minimize the risk of interference.

By adjusting the transmission power to a level for each station pair that exchange information to achieve a certain expected transmission qulity the level of interference is minimized and the information exchange is not performed with an unnecessary high quality. Fig 15b shows power diagrams 25, 26 for different stations situated at different distances from their central stations. In order to maintain a desired transmission quality in the system in unpredicted situations is fault detection applied. The influence from interference can be decreased by adapting forward error correction codes or by changing time slots or frequency.

When a system according to the present invention is used for duplex transmission information packages to or from a central station are coordinated with respect to time intervals. In that way losses due to directional changes in time and capacity are minimized. Fig 16 and 17 show how the antenna system of one central station for one radio unit is directed in one specific direction at the time T1 and transmits and receives information packets to and from a peripheral station 20. At point T2 another packet is received at the central station from the peripheral station 19 and its corresponding packet is sent out to 19, in duplex mode.

Fig 18 shows a similar process as described with reference to fig 16 and 17 but at different time slots T1, Tn, T5, Tk in semi duplex mode. The transmission process is separated between the central station and the peripheral stations as illustrated in the antenna diagram 38 and 39. 44 is the information packets sent by a central station and 45 is the information sent by the peripheral station. In semi duplex mode the central station coordinate the traffic flow to and from the peripheral stations and direct the antennas towards incoming packages from peripheral stations shortly before the information 45 is received by the antenna. Shortly after the transmission is completed the antenna is redirected. A central station controls each of the peripheral stations associated therewith with respect to the time intervals during which the peripheral station is allowed to transmit information. In that way the central station knows when information will be transmitted from each of the peripheral stations and when the information will be received. When such a package is received the antenna lobe 38 has just taken the proper direction. During the rest of the time period of each frame the central station exchanges information with other peripheral stations and in the next frame the antenna is again directed towards the mentioned station as long as the time slot is assigned.

Fig 19 shows the duplex frame structure for one or several central stations 1..n. The transmission and receiving time are illustrated at 35 and 36. The total amount of time available during one frame is referenced by 32. One frame is devided into certain slots 320. The relative time difference between geographically separated central stations is referenced by 34.

Fig 20 shows the semi duplex mode where each subsystem or central station using the same radio carrier is separated in a transmission time for the central station and the peripheral stations 38 and 39. The total time for one frame for both directions is referenced by 33. The time slot assigment in each of the directions can be different which is shown at 380 and 390 in semi duplex mode the transmission direction to and from the peripheral stations is controlled by time slot allocation reservation which makes it possible to handle traffic of different capacity between ports in the system independently of the transmission direction. The semi duplex frame structure is separated in a transmission time period and a receiving time period in order to operate several different central stations at the same time on the same frequency, see fig 22, with minimized interference between subsystems. Said central stations can be adjacent or non-adjacent.

Fig 21 and 22 show an exemple of an implamentation of the system over a wide area. One or several central stations 10 form subsystems 50 together with peripheral stations 11 and 12. One or several central stations can be formed as one station or super central station 40 at the same site via a digital switch. The traffic within or between different subsystems may take place through an external digital switching device 90 in order to increase redundancy or to use each super central station more efficiently. Several subsystems 50 form a system 70. Synchronisation and coordination between subsystems and inter system data exchange is shown at 80. Connection ports to other networks are represented by 31 and 91 at the central or super central stations and by 310 at the peripheral

stations. Coexistance of two subsystems that cover the same region is shown in figure 22, c.

Fig 23 shows one subsystem 50 and under the central station 10 one or several separated peripheral stations 11 and 12 with its ports 310 where user traffic is to be connected. Use of data transmission is represented by 500. Signalling between central and peripheral stations is represented by 800 for the ports and by 900 for other signalling. Interference is further possible to minimize in the system by analysing the user information which is required to be sent through each subsystem. If so desired only information packets that carries changes or certain types of changes are transmitted through the system. When information is considered redundant and is not transmitted the information is instead reinserted at the corresponding destination port of the system. The information transfer between ports is controlled in the signalling 800 which requires less band width than usual data transfer 500. Data, such as silence or "on hook condition" in a telephone system and/or repaeted similar data streams or no data transmission from a computer, LAN, PABX, IMAGES, etc can be controlled by signalling between the stations. In this way the interference in the system is decreased. Further, the system capacity will be increased.

Fig 24, 25, 26 show examples of different system configurations. In fig 24 each of the super central stations or subsystems is connected to another network 72. In fig 25 connection to another network is made through one super central station or subsystem only, inter traffic between stations shown at 1000. Fig 26 shows a more complex and

decentralized structure where some super central stations or central stations are terminated to other networks and some are not.

By allowing a plurality of geographically adjacent subsystems each having a possibility to cover 360^{o} horizontally while using the same frequency, the frequency space effenciency is increased by a factor from 7 to at least 14 in relation to other methods, see fig 4, of wide radio, area networks. As the antenna system may also include vertical space control and as different users are separated in variable altitudes such as sky scrapes the factor is further increased.

When each central station is equipped with an antenna each covering a sector of 90^{o} horizontally the frequency efficiency is still further improved by a factor of about 4 when interferance is controlled efficiently. If such an arrangement includes two or more systems to cover the same area from the same site 51 the efficiency is still further improved. Each central and peripheral station is equipped with ports that allow multiplexed or unmultiplexed digital signals to be transmitted through the system. The ports 31; 91; 310 form the connection points between the users and the system. Said ports are designed in such a way that it is possible to achieve a secure and if required a compressed information exchange through the system for each service connected. This is done in order to avoid interference and to delete unnecessary information transfer which at some time intervals carries no significant data, see fig 23. This further improves the frequency efficiency and the interference risks are further decreased.

The secrecy of the system according to the present invention is also improved dramatically when information is transmitted in packages in different directions. By adjusting the transmission intensity in dependence of the actual traffic and quality needs the secrecy is further improved.

CLAIMS

1. Method in a wide area radio communication network, the network comprising at least two central stations (10), each central station being assigned to at least one peripheral station (11), c h a r a c t e r i z e d in that during all time intervals radio transmission at specific frequencies between stations positioned along an arbitrary line is coordinated.

2. Method according to claim 1, c h a r a c t e r i z e d in that coordination data is determined in advance, and that said data is provided at said central stations.

3. Method according to claim 1, c h a r a c t e r i z e d in that information transfer coordination is arranged between subsystems adaptively along with the dynamical changes by using quality detection codes.

4. Method according to claim 1 or 2, c h a r a c t e r i z e d in that information concerning the location of stations desposed at a predetermined distance from a central station is stored in that central station, that transmission direction and transmission intervals of the peripheral stations assigned to that central station is calculated from said information, and that said transmission data is stored in each of said peripheral stations.

5. Methods according to claim 1, c h a r a c t e r i z e d in that the transmission direction at each central station is optimized with regard to the position of each corresponding station.

6. Method according to claim 5, c h a r a c t e r i z e d in that the energy transmitted by each pair of stations communicating with each other is controlled and coordinated.

7. Method according to any of the preceeding claims, c h a r a c t e r i z e d in that information which is to be transmitted via the system continuously is analysed with regard to the contents thereof in relation to previously transmitted information and that redundant information is prevented from being transmitted.

8. Method according to any of claims 1-6, c h a r a c t e r i z e d in that error detecting codes are added to signals transmitted in the network, and that on detection of an error caused by interference of radio signals, transmission data is changed so as to eliminate the error.

9. System in a wide area radio communication network carrying out the method according to any of the preceding claims, the network comprising at least two central stations (10), each central station (10) being assigned to at least one peripheral station (11; 12; 19, 20), c h a r a c t e r i z e d in that the stations are provided with timing means (13) for transmitting during predetermined time intervals, and transmitting and receiving means (14; 41, 42) for transmitting and receiving in a predetermined direction.

10. System according to claim 5, c h a r a c t e r i z e d in that the central stations are provided with means for receiving and storing time coordination signals.

11. System according to claim 5 or 6, c h a r a c t e r i z e d in that each of the central stations is provided with storing means for storing information concerning the location of stations disposed at a predetermined distance from that central station, and that each of the central stations is provided with calculating means for calculating transmission data for the peripheral stations assigned to that central station.

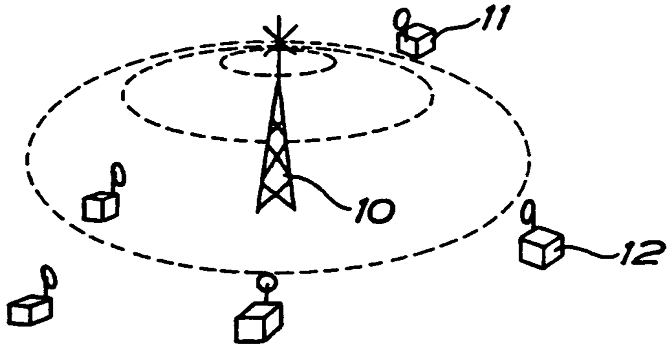


FIG. 1

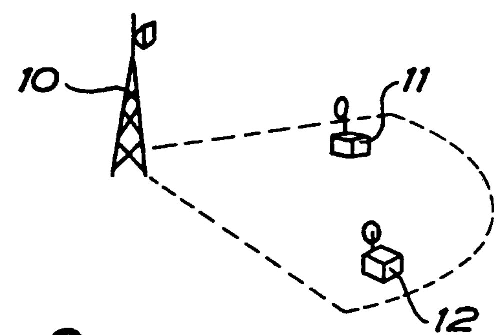


FIG. 2

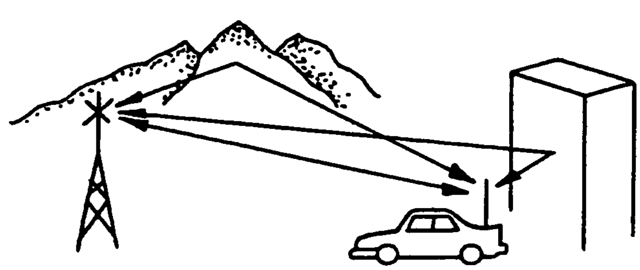


FIG. 3

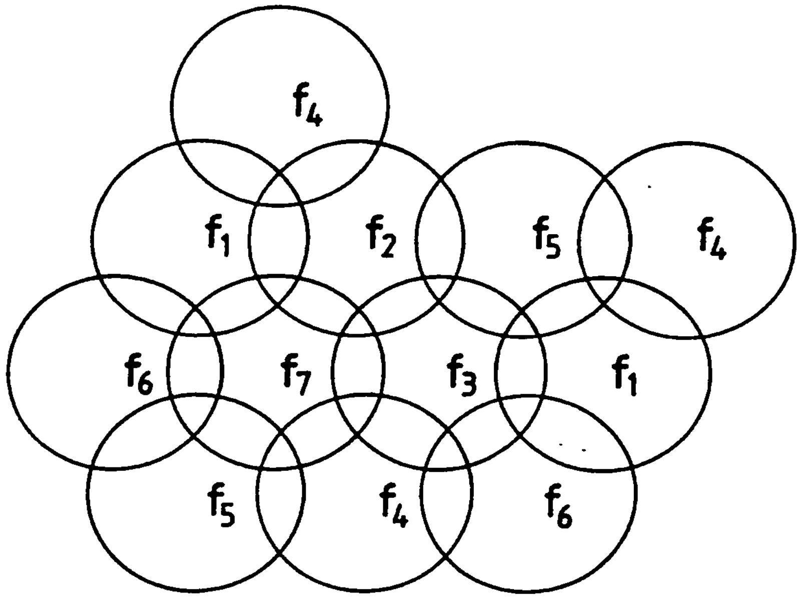


FIG. 4

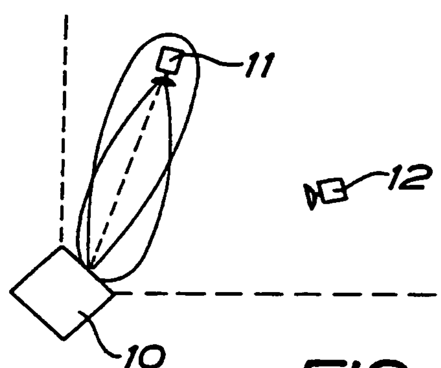


FIG. 5

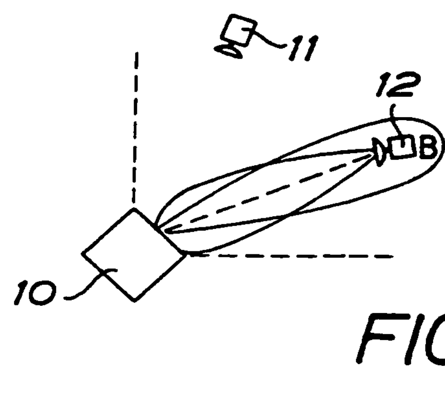


FIG. 6

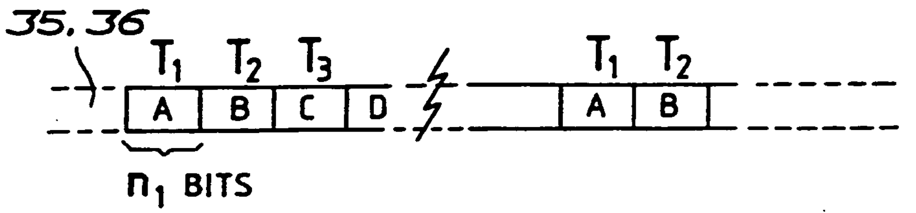


FIG. 7

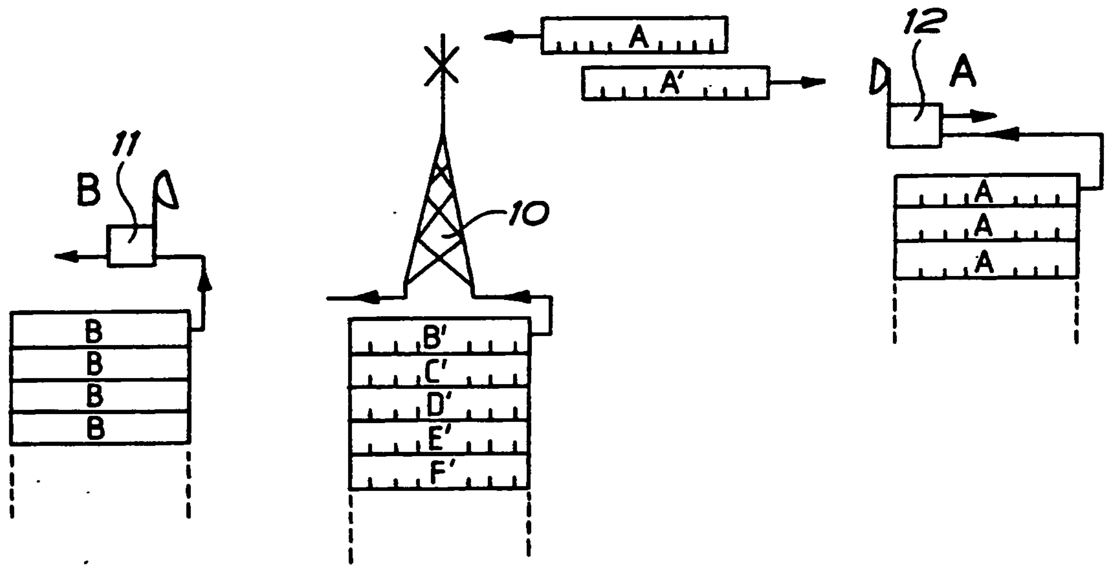


FIG. 8

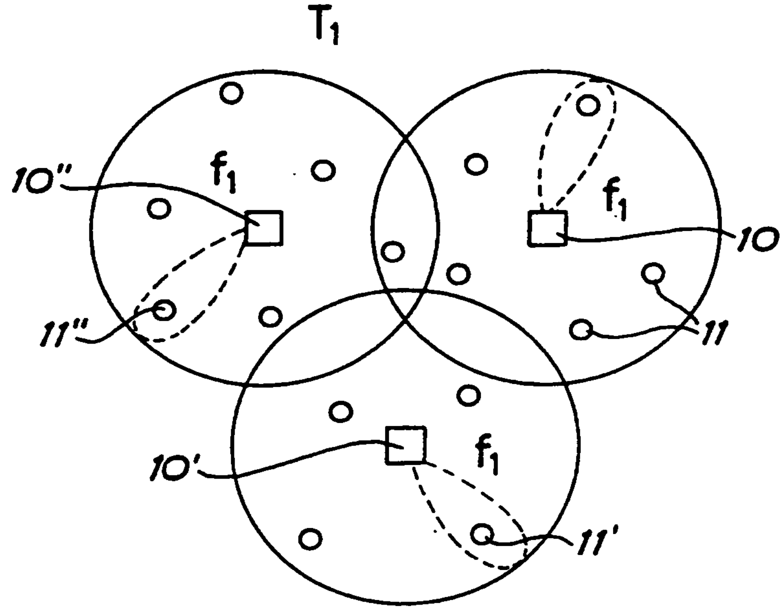


FIG. 9

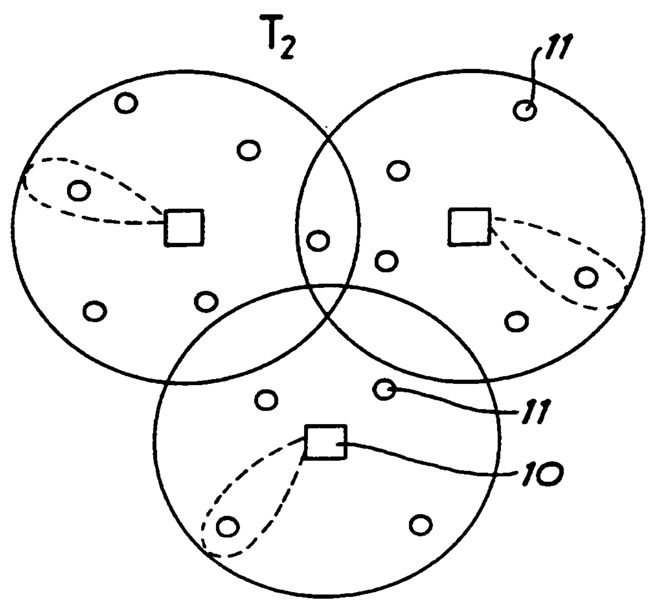


FIG. 10

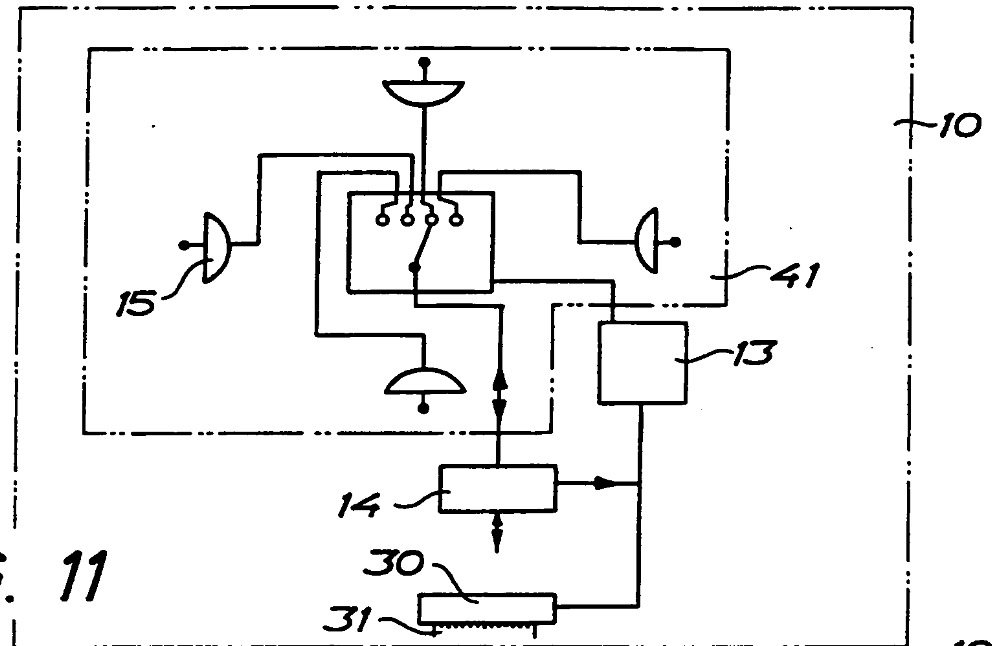


FIG. 11

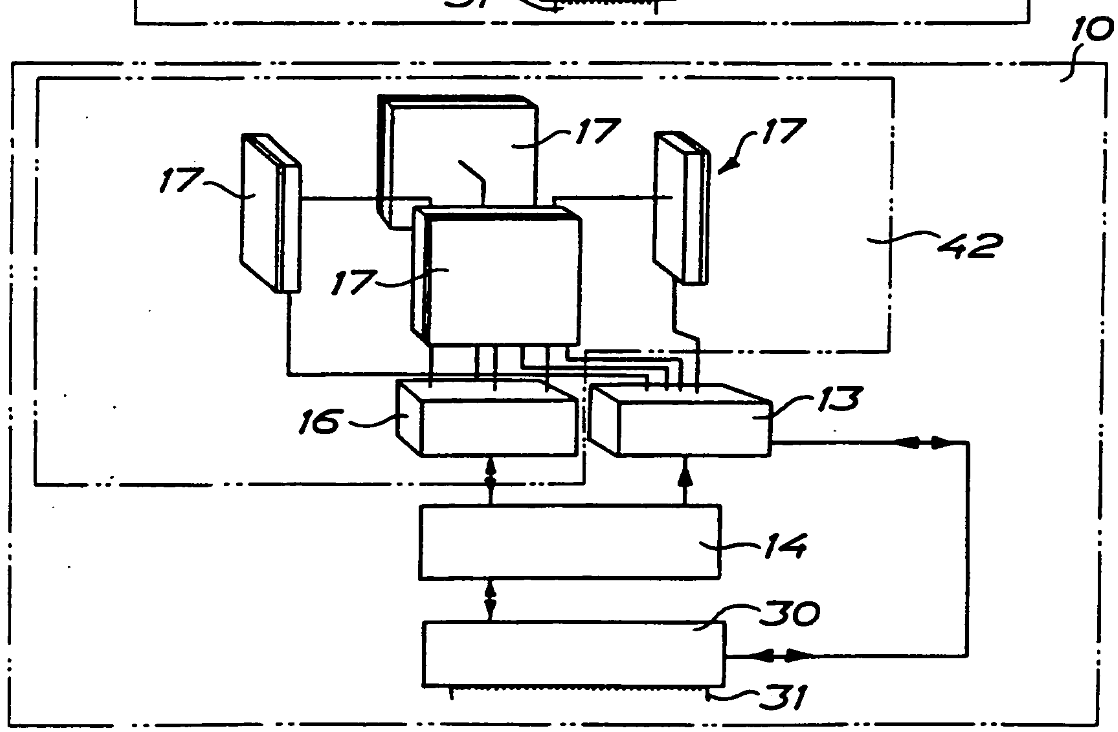


FIG. 12

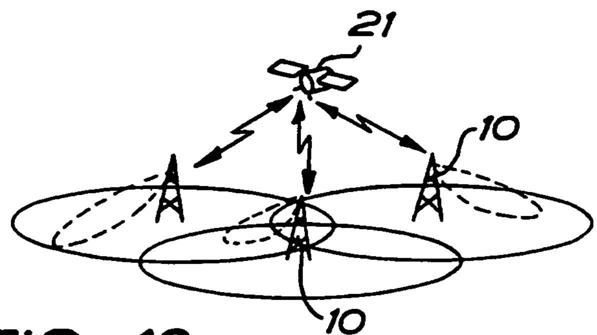


FIG. 13

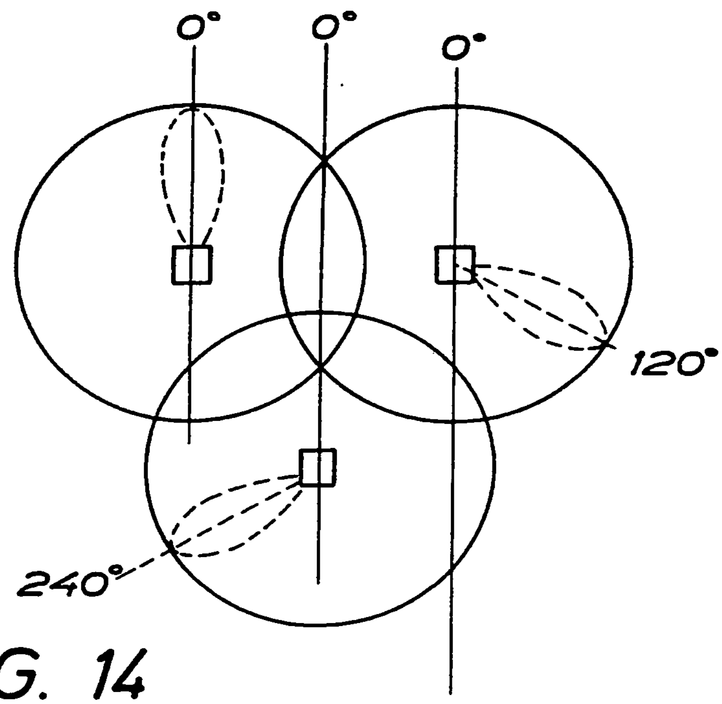


FIG. 14

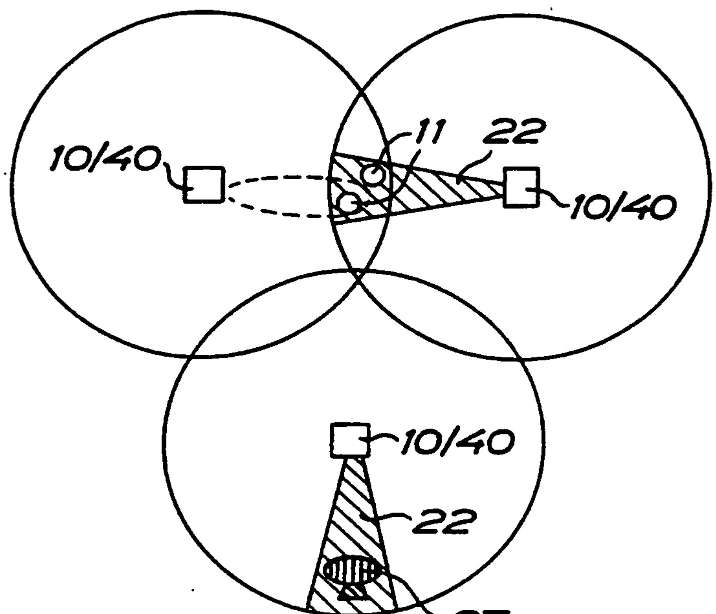


FIG. 15a

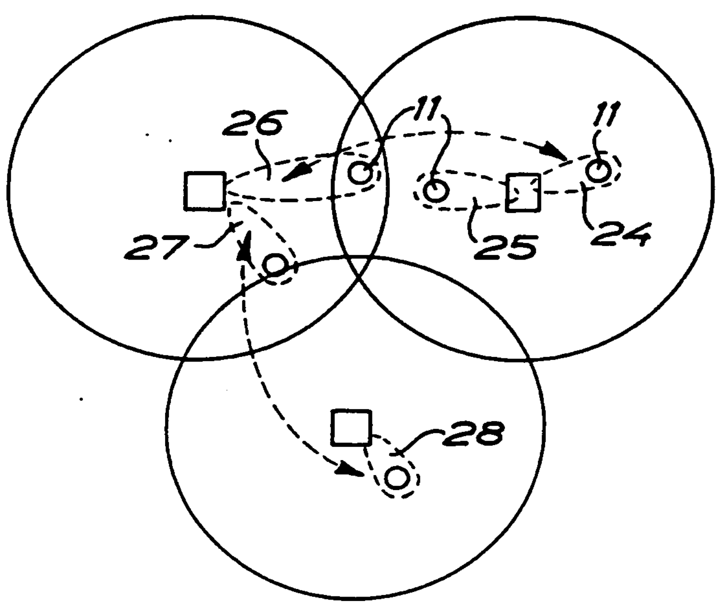


FIG. 15b

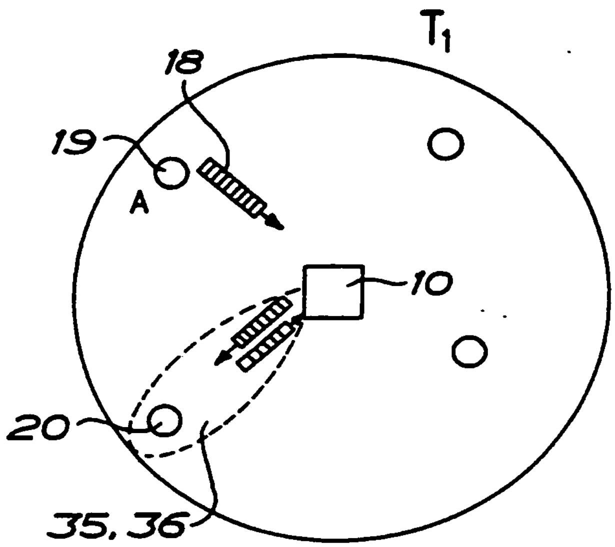


FIG. 16

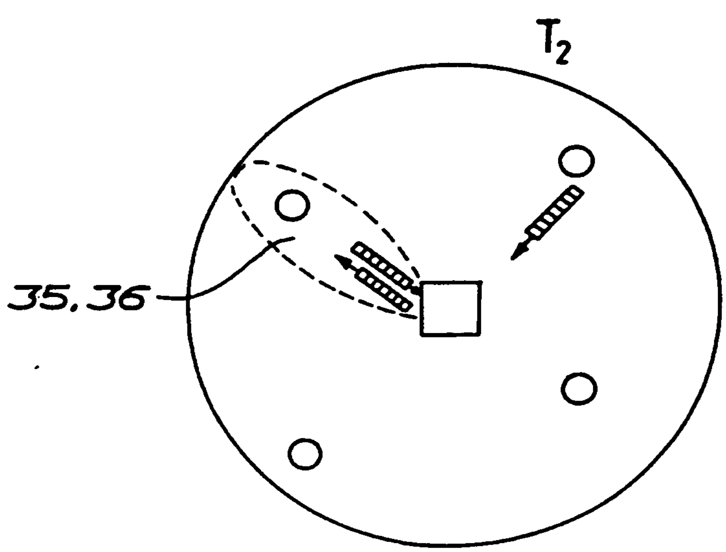


FIG. 17

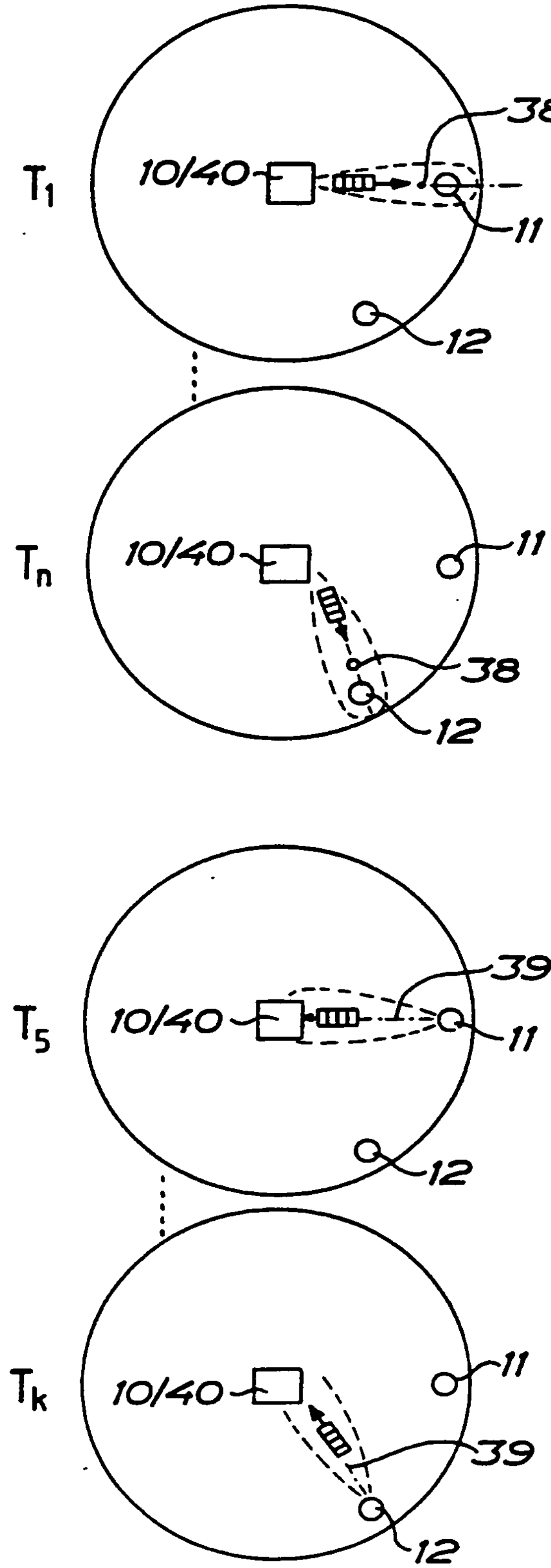


FIG. 18

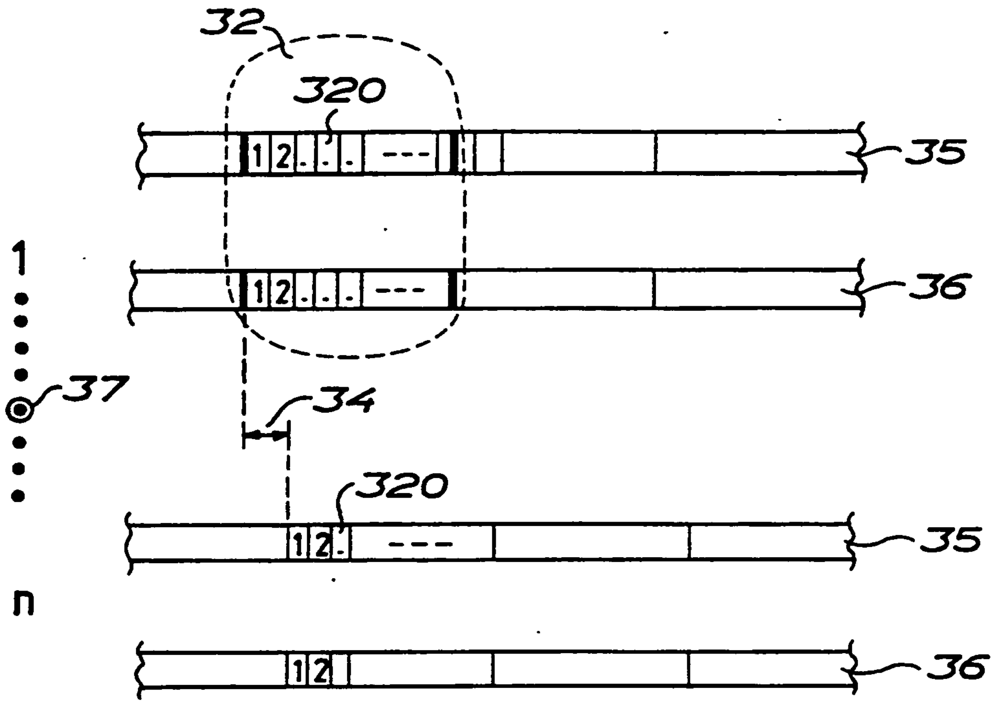


FIG. 19

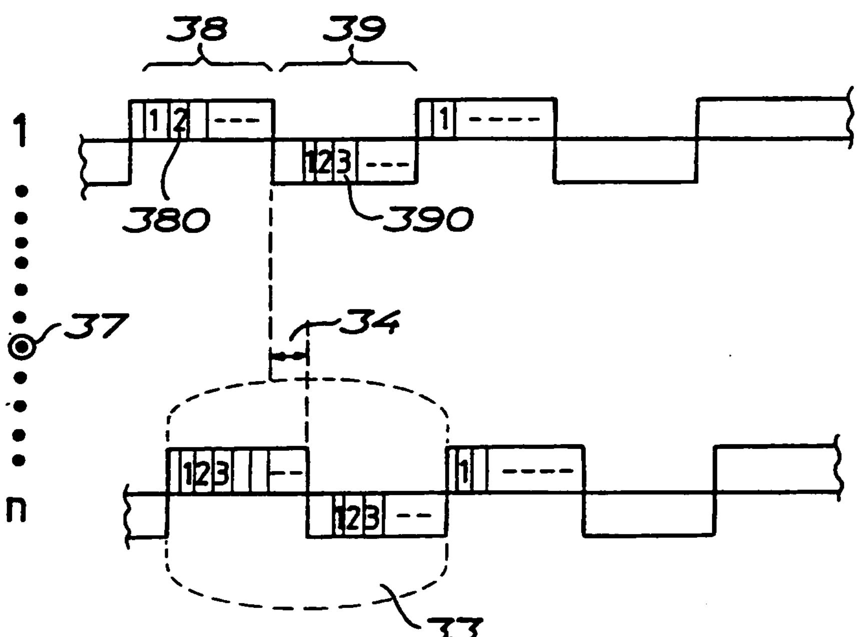
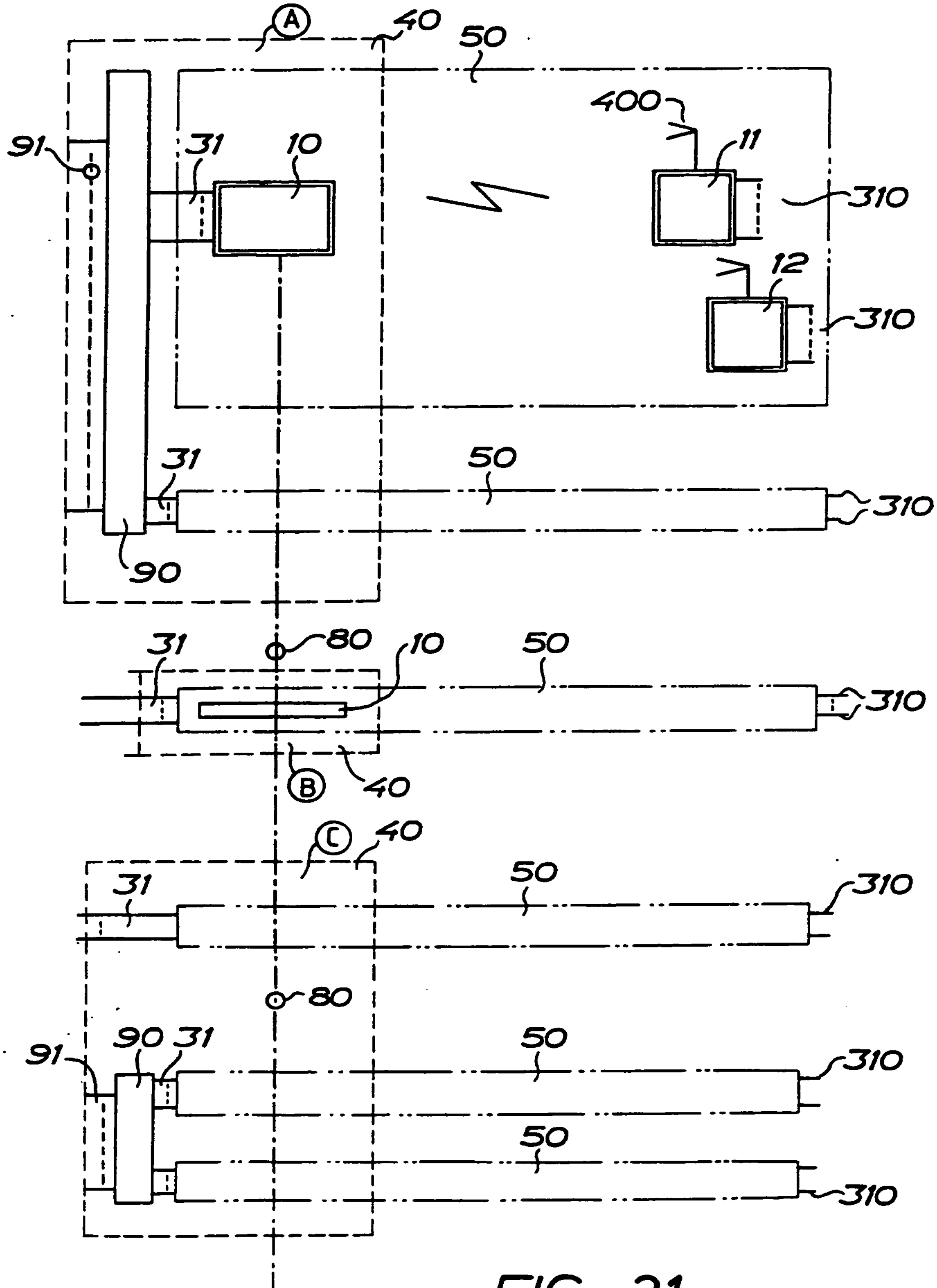


FIG. 20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91
90
31
50
310
50
310

FIG. 21

T 380

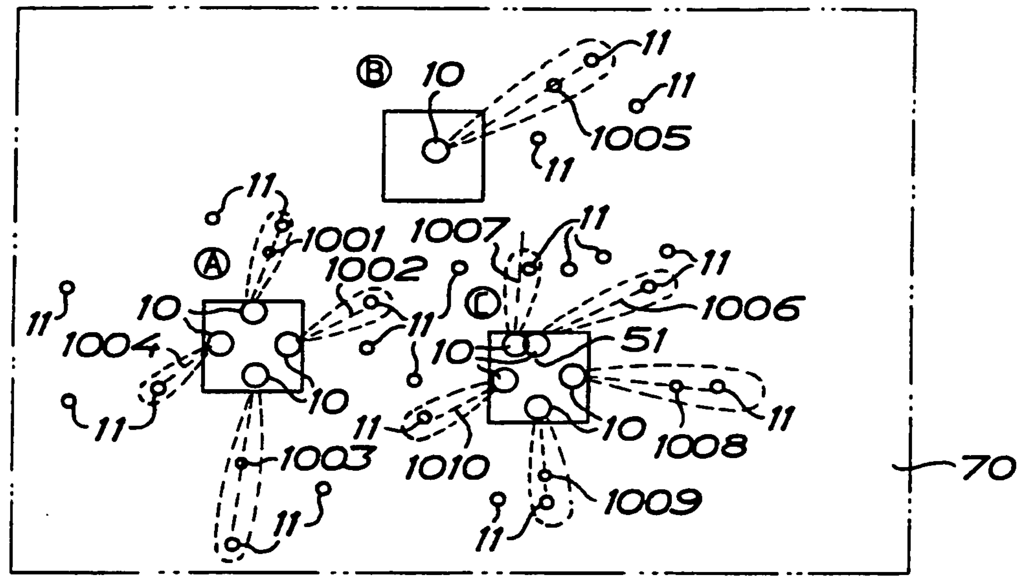

FIG. 22a

T 390

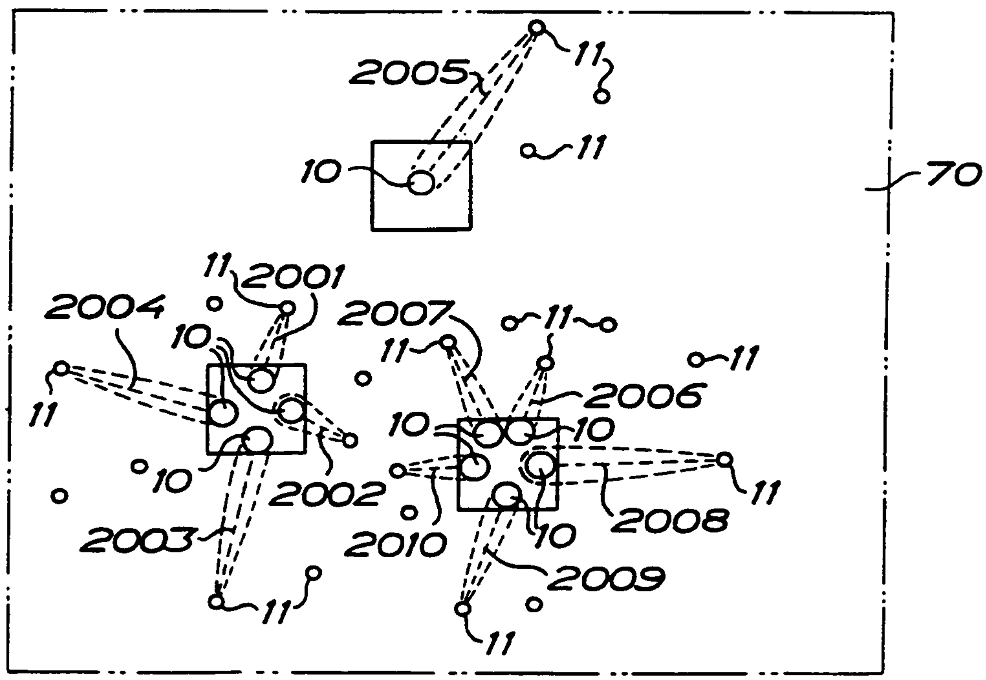

FIG. 22b

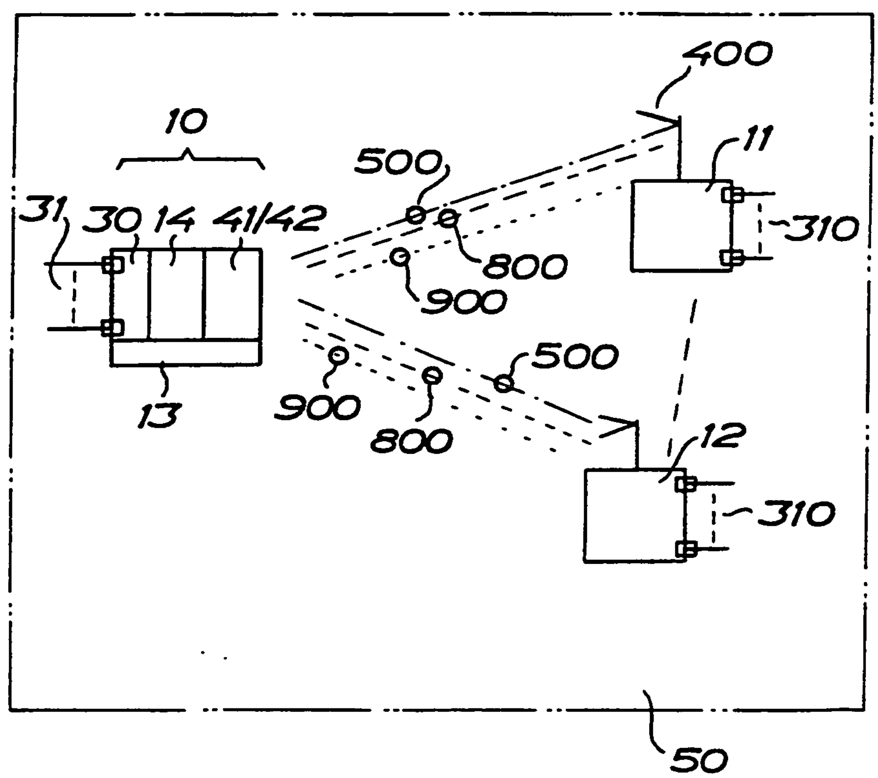

FIG. 23

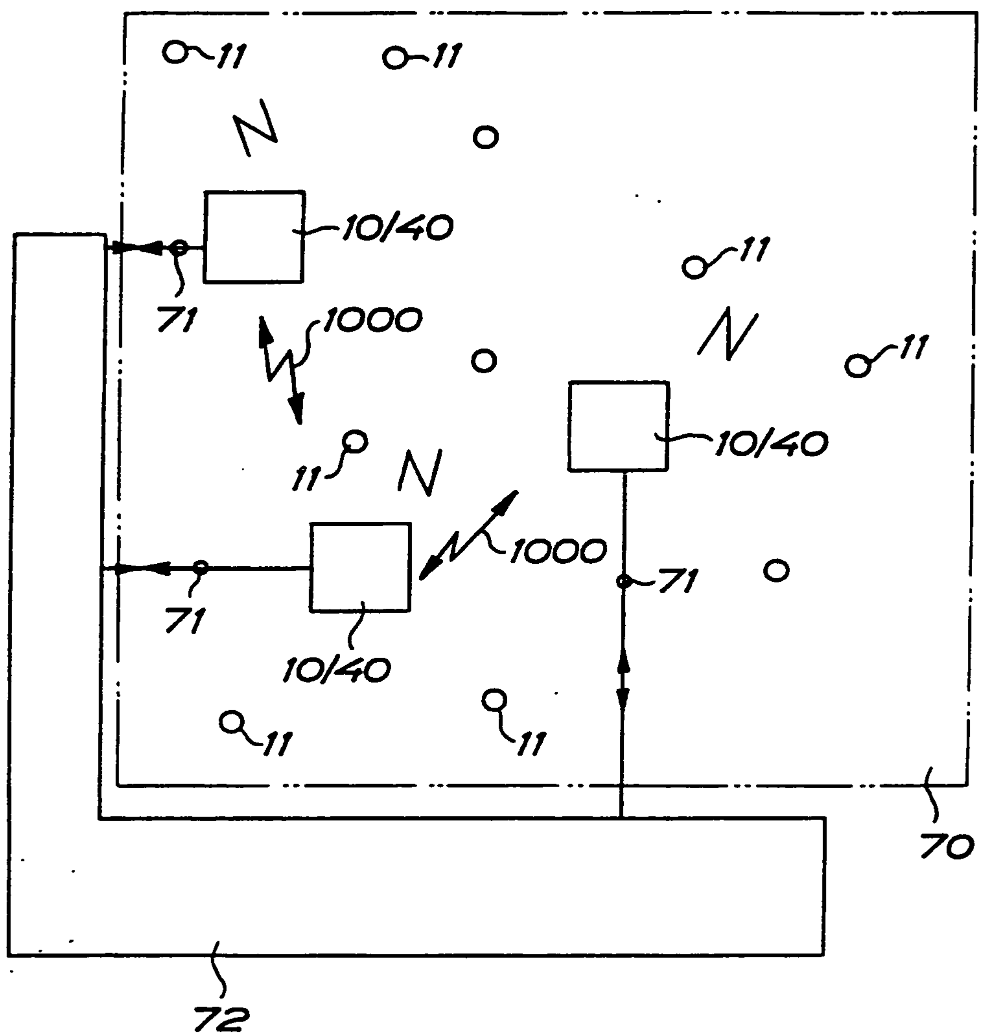

FIG. 24

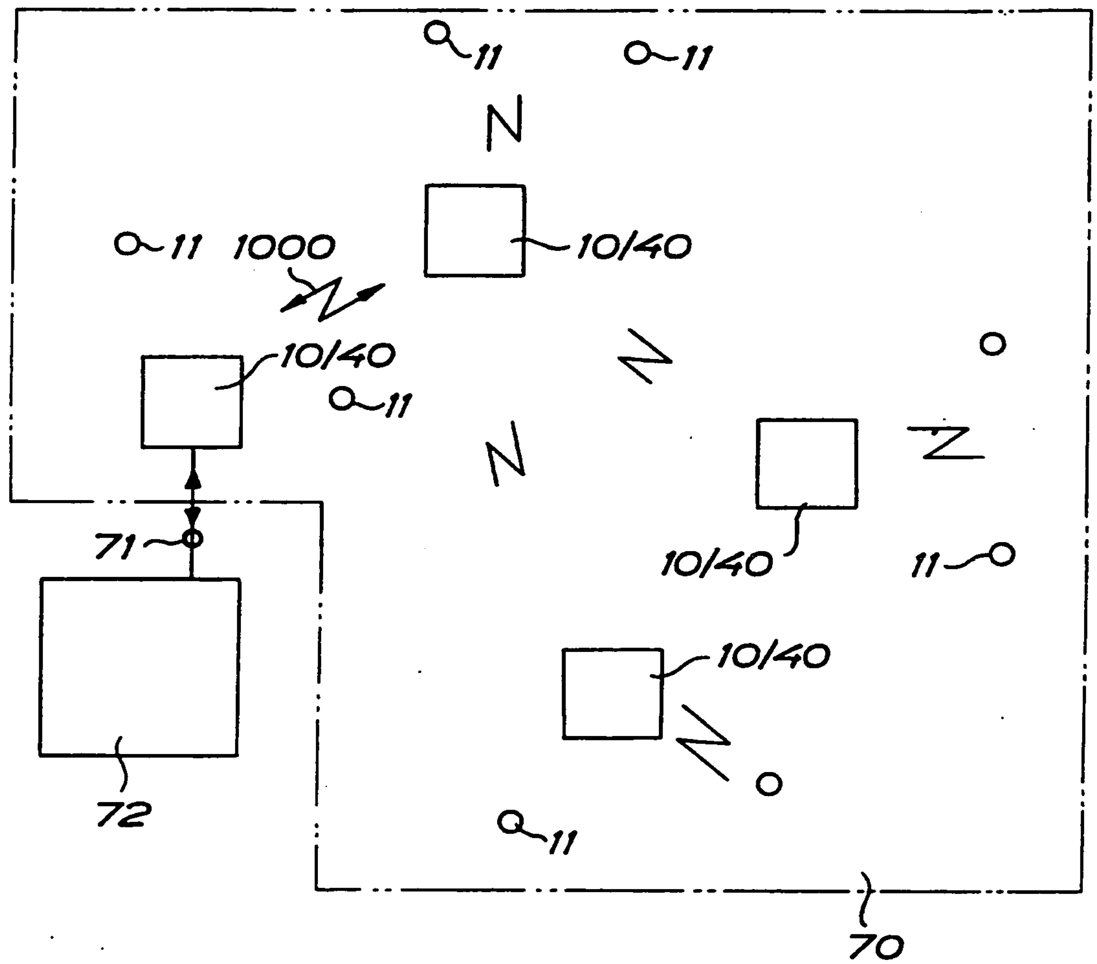

FIG. 25

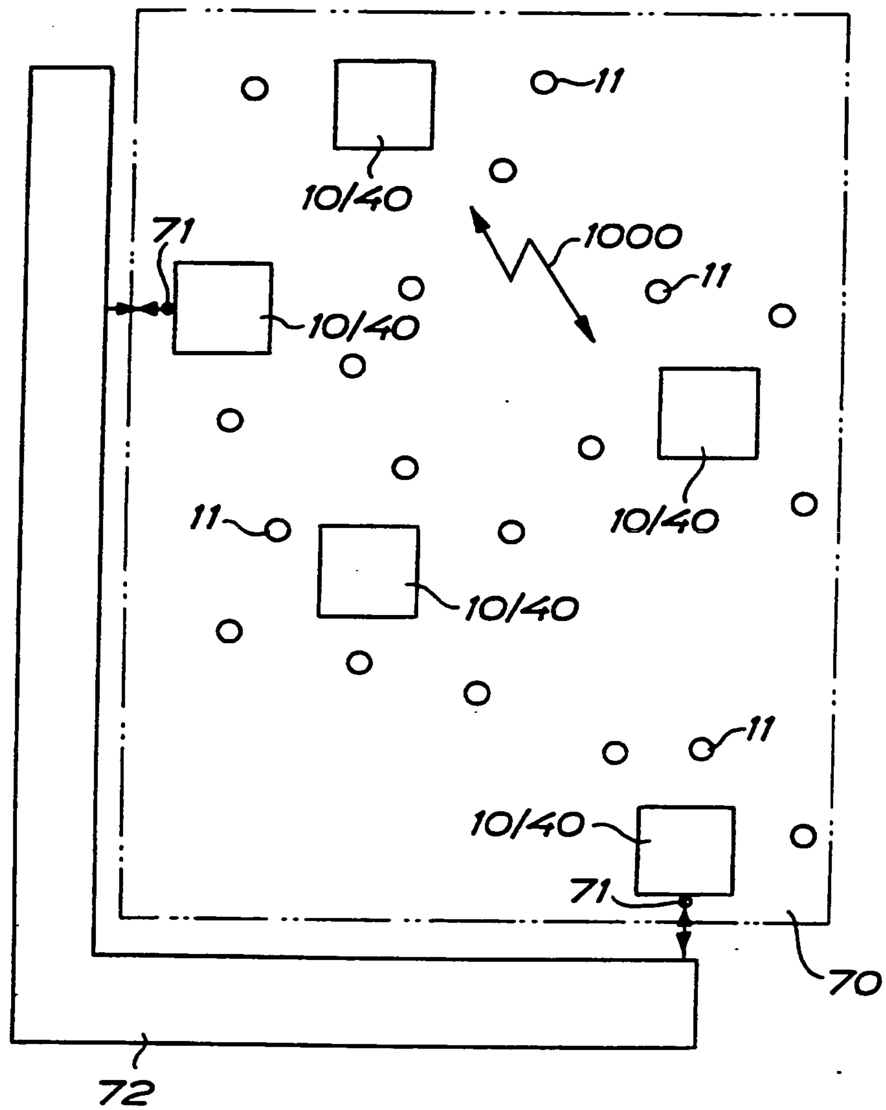

FIG. 26

INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 89/00470

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC 4

IPC4: H 04 B 7/26

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC4	H 04 B, H 04 J, H 04 L, H 04 Q

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 4414661 (K.KARLSTRÖM) 8 November 1983, see column 2, line 24 - line 42; column 3, line 15 - column 4, line 26; figures 1,2 --	1-3
X	US, A, 4633463 (A MACK) 30 December 1986, see column 1, line 66 - column 2, line 62 --	1-3,9, 10
X	EP, A2, 201254 (A. ACAMPORA ET AL) 12 November 1986, see page 4, line 35 - page 6, line 3; figures 3,4 --	9

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1989-11-16	1989 -11- 21
International Searching Authority	**Signature of Authorized Officer**
Swedish Patent Office	Göran Magnusson

International Application No. PCT/SE 89/00470

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	US, A, 4144496 (M. CUNNINGHAM ET AL) 13 March 1979, see figure 8A --	1,9
A	US, A, 4759051 (K. HAN) 19 July 1988, see figure 1 -- --------	1,9

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. PCT/SE 89/00470

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4414661	08/11/83	EP-A- 0069275	12/01/83
		AU-D- 85164/82	06/01/83
		JP-A- 58013038	25/01/83
		CA-A- 1177979	13/11/84
US-A- 4633463	30/12/86	NONE	
EP-A2- 201254	12/11/86	AU-D- 57084/86	06/11/86
		JP-A- 62010997	19/01/87
		AU-A- 564221	06/08/87
		US-A- 4730310	08/03/88
		CA-A- 1250647	28/02/89
US-A- 4144496	13/03/79	NONE	
US-A- 4759051	19/07/88	GB-A- 2203018	05/10/88